

Title Page

Title: Advancing Quality Measurement and Care Improvement with Health Information Exchange

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Structured Abstract (Select for Elements).

Purpose: The goal of this project was to leverage community-wide, real-time clinical data from a health information exchange (HIE) to 1) improve the identification of early (72-hour) emergency department (ED) returns and enhance the performance of an ED-based quality assurance (QA) program, and 2) create an automated, real-time, HIE-based alerting system to improve the identification of frequent ED users for an existing case management intervention.

Scope: Aim 1) To validate the use of HIE data for our two quality measures when compared with site-specific EHR data, Aim 2) retrospectively measure the change in our ability to employ these measures using HIE data, and Aim 3) implement these HIE-enhanced measures and prospectively measure changes in their performance.

Methods: Aim 1) retrospectively compared measures using HIE data to site-specific EHR data provided by four sites to validate use of HIE data, Aim 2) conducted retrospective observational studies comparing use of HIE-wide to site-specific data for both measures, and Aim 3) built, implemented and measured the performance of a) a monthly HIE-based early (72-hour) ED returns report in an existing QA program and b) a real-time, HIE-based frequent ED user notification service.

Results: Use of HIE data were validated in Aim 1, significantly increased ability to identify both early (72-hour) return visits and frequent ED users were found in Aim 2, and an increased ability to identify and intervene on both populations was found in Aim 3.

Key Words: *Health information exchange, HIE, electronic health record, EHR, early 72-Hour Return, ED Returns, Frequent ED Users*

Purpose (Objectives of Study).

The goal of this proposal was to create and validate health information exchange (HIE)-enabled versions of two quality measures for potentially preventable emergency department (ED) visits: 1) *early (72 hours) ED returns* and 2) *frequent ED users*, then evaluate their impact on interventions compared to “siloeed” site-specific data. The project was implemented with Healthix, one of the largest HIEs in the country that spans most of the major hospitals in the New York City (NYC) metropolitan area.

The specific hypotheses in this proposal are that **1)** HIE-enabled quality measures increase detection of ED quality assurance (QA) cases and frequent ED users compared with site-specific data and **2)** use of these measures in ongoing QA and case management programs will improve these programs performance.

The aims of this project were **1)** develop and validate a HIE-based tool to support new inter-institutional quality measures for early (72-hour) ED returns and frequent ED users, **2)** compare the performance of the new HIE-enhanced measures to existing measures based on site-specific data and **3)** implement the HIE-based quality measures in existing QA and case management programs and measure the impact.

The **primary outcomes** included the number of patients captured in the 72-hour return and frequent ED user cohorts with and without the HIE-enhanced measures. **Secondary outcomes** included the number of 72-hour return cases constituting quality issues, and the number of visits by frequent ED users with and without the new inter-institutional measures.

Scope (Background, Context, Settings, Participants, Incidence, Prevalence).

Background

Emergency departments (EDs) are in the midst of a crowding crisis.(1-5) While the number of ED visits increased from 90.3 million in 1996 to 123.8 million in 2008 (a 37% increase), the number of hospital EDs decreased from 4,019 to 3,833 and the ED utilization rate increased 21% from 34.2 to 41.4 visits per 100 persons.(6-9) By 2014 the number of ED visits had increased to 141.4 million, with 45.1 visits per 100 persons.(10) Crowding has been associated with increased morbidity and mortality in nearly every disease condition studied (11-16), which makes ED crowding a substantial quality problem in the US. Indeed, AHRQ has identified ED crowding and boarding (i.e., holding admitted patients in the ED until an inpatient bed is available, in some cases for days), as factors that raise concerns about the quality of care delivered in EDs. They have identified potentially preventable ED visits as a specific measure to be used in evaluating the effectiveness of care coordination interventions aimed at reducing these visits. This proposal addressed two major types of potentially preventable ED visits: early (72 hours) ED returns and visits by frequent ED users (17).

The goal of this proposal was to leverage the data in an existing health information exchange (HIE) to improve quality measurement in an ongoing early (72-hour) ED returns quality assurance (QA) program, and decrease visits by frequent ED users. While there has been much activity across all 50 states to create HIEs, these were largely motivated by the primary clinical use case of an individual provider, caring for an individual patient, seeking additional information from outside of his or her organization in order to create a more comprehensive longitudinal record and a more complete picture of the patient. As a byproduct of this work, we have essentially created a new data layer in our health care information ecosystem, which represents, really for the first time, an ostensibly community- or region-wide, real-time clinical dataset. This new data layer represents a tremendous opportunity for new and innovative interventions to be built as secondary use cases that could revolutionize the way in which we deliver care. Since quality measurement is usually done in an institution-specific way, with data sources limited to single provider organizations, we planned to leverage HIE as a data source to allow community-wide quality measurement. Using innovative HIT tools implemented with the Healthix HIE (formerly the New York Clinical Information Exchange (NYCLIX)), we created and validated 2 HIE-enabled measures for potentially preventable ED visits by: 1) *frequent ED users* and 2) *returns to the ED within 72 hours (72-hour ED returns)*; then implemented and evaluated these measures in programs aimed at improving ED quality measurement and reducing potentially preventable ED visits.

Setting

The study began at Mount Sinai Medical Center (MSMC) in New York City, where the PI was an Associate Professor in Emergency Medicine, and much of the work, including technical development and the majority of data collection was to be done through the New York Clinical Information Exchange (NYCLIX). In July 2013 MSMC merged with Continuum Health Partners,

another multi-hospital health system, creating the Mount Sinai Health System, where the PI is now a full Professor in Emergency Medicine with tenure (promoted in 2016).

The Mount Sinai Health System is an integrated health care system providing exceptional medical care to our local and global communities. Encompassing the Icahn School of Medicine at Mount Sinai and seven hospital campuses in the New York metropolitan area, as well as a large, regional ambulatory footprint, Mount Sinai is acclaimed internationally for its excellence in research, patient care, and education across a range of specialties.

Additionally, NYCLIX merged with the Long Island Information Exchange (LIPIX) in 2012, and then with the Brooklyn Health Information Exchange (BHIX) to form Healthix, which has continued to serve as the PIs "lab". Healthix is now considered to be one of the largest HIEs in the country, with more than 16 million unique patients, more than 60 hospitals, and more than 4400 sites. Healthix remains an important partner in Dr. Shapiro's ongoing projects.

Mount Sinai is an active member of Healthix and has multiple subcontracts in place with them to support federally funded interoperability projects. Mount Sinai has integrated the Healthix Web-based clinical portal with the Epic EHR, allowing users "single click" access via a "deep link" that launches the Healthix clinical portal into a specific patient's record from within Epic. This obviates the need for a separate user login or patient lookup, which has greatly facilitated adoption and usage by clinical users. Healthix also provides automated clinical event notifications to Mount Sinai in support of care coordination efforts. When these notifications arrive from Healthix, they are integrated into the patient's record in Epic as an encounter, sent to appropriate users as secure "in-basket" messages within Epic, sent to users via secure email, sent to internet protocol telephones of users via text message, and written to a data file on a secure server for monthly reports and analytics. Mount Sinai and Healthix continue to hold multiple weekly project status conference calls to discuss ongoing projects and many other working meetings as needed on a weekly basis, including a weekly call for Dr. Shapiro's projects that includes Healthix leadership.

Methods (Study Design, Data Sources/Collection, Interventions, Measures, Limitations).

Methods

Aim 1: Develop and validate an HIE-based tool to support new inter-institutional e-Quality measures that detect 72-hour ED returns and frequent ED users.

As mentioned in the progress reports for years 1, 2 and 3, instead of first developing the HIE-based tool to extract data for the validation work of AIM 1, the decision was made to gather data directly from the HIE and from the sites' EHRs through standard query methodology to perform the validation analysis. Data from four hospitals, Mount Sinai Hospital, Beth Israel Hospital and Saint Luke's Hospital and Roosevelt Hospital (prior to the later merger), were gathered for this purpose. Separately, data from Healthix was gathered. Electronic health record (EHR) and HIE data elements were obtained for all ED visits from 3/1/09 to 2/28/11, including visit number (denotes a unique encounter), medical record number (MRN – denotes a unique patient), admission and discharge date and time, date of birth, and gender. All data were de-identified in accordance with HIPAA prior to analysis by the research team, and the protocol was reviewed by the Mount Sinai Office for the Protection of Human Subjects and given a not human subjects research determination.

Preliminary results from these analyses from the first site were presented at both the American College of Emergency Physicians in October 2013ⁱ and at the American Medical Informatics Association in November 2013ⁱⁱ, and preliminary results of our analysis for all four sites was presented at SAEM in May of 2014.ⁱⁱⁱ An additional poster showing the use of a Cohen's kappa metric to validate the HIE data was presented at ACEP 2014.^{iv} A complete manuscript of the final multi-site analysis was presented as a proceedings paper through a podium presentation at AMIA 2014.^v The major findings of this work were to validate the use of HIE data for frequent ED user and early ED return measurement across four hospitals by comparing site-specific data from the HIE to data provided from each site's EHR. Methods from this full paper follow in the next few paragraphs, and results are presented in the next section under "Aim 1".

HIE and EHR data for each site were merged on hashed visit numbers to evaluate concordance of unique encounters, and on hashed MRNs to evaluate concordance of unique patients. In this case, concordance is defined as having a unique match. Next, age, gender and the time-stamps for admissions/discharges were also tested for concordance. In order to adjust for differences between the EHR and HIE data for these latter four parameters, various data cleaning rules were systematically applied. These data cleaning techniques were derived from observation of the major areas of discrepancy noticed when concordance between the two data sets was tested, and through expert evaluation of workflow issues that were likely to have caused these discrepancies at each site. The three data cleaning techniques used were as follows: 1) Age was considered to match if the date of birth was less than or equal to one year difference between the HIE and EHR data. 2) Gender was considered to match if it was specified in either the EHR or HIE, and recorded as the same or "unknown" in the other system. 3) Admit and discharge times were considered to match if the difference in date/time was less

than 6-24 hours. The number of hours from 6-24 was chosen on a site-specific basis by extending the data cleaning factor by the smallest multiple of 6 hours in which the concordance of encounters first became greater than 98%. This particular data cleaning technique was necessary because differences in clinical and registration staff workflows likely led to small but frequent discrepancies between the two data systems in which admit and discharge times were entered. For instance, when a clinician discharged an ED patient, a date/time stamp was immediately entered in the EHR but the registration staff member may wait until the end of his or her shift to remove the patient from the ADT system, causing the ADT date/time stamp to lag behind by a small number of hours.

The last part of the data analysis included measuring frequent ED users (patients with ≥ 4 visits in 30 days) and early (72-hour) ED returns (patients who return for a second ED visit within 72 hours of being discharged). The counts for each of these quality measures were then compared for statistically significant similarity between HIE and EHR datasets for each hospital using Chi square.

Aim 2: Compare the performance of these new inter-institutional e-Quality measures to current site-specific measures with quantitative and qualitative methods.

For this aim, we followed a number of approaches and published a number of abstracts and papers, and currently have a final paper under review. These included:

- 1) A retrospective observational study across 10 EDs measuring the increased ability to detect frequent ED users with HIE data when compared to site-specific data. An aggregate, de-identified data set of all patients with at least one instance of four or more ED visits across the 10 NYCLIX sites in a 30-day period during the study period (6/1/10 and 5/31/11) was provided by the HIE for further analysis. Visits occurring within six hours of another ED visit at the same site were excluded based on local expert opinion, and because this exclusion biased us in favor of our null hypothesis. Administrative leadership at several EDs believed repeat visits to the same site within six hours may disproportionately represent common administrative/clerical errors in recording ED admissions and account for instances where patients were electronically discharged prematurely and then reregistered. For each site and for the HIE as a whole, we calculated (i) the number of ED visits, (ii) the number of patients accounting for these visits, (iii) average number of ED visits per patient (for the 12-month study period), (iv) the number of patients who were frequent users according to our definition, (v) the number of ED visits that were accounted for by the frequent ED users, (vi) and the average number of visits per frequent ED user. We calculated the percent increase in the number of frequent ED users and frequent ED visits that occurred using data from across the entire health information exchange. For calculation of observed and expected counts of frequent ED users, chi square analysis was performed. For all other analyses the Wilcoxon signed-rank test was used because the distributions of visit and patient counts were skewed. Alpha was set to 0.05 for all analyses. This study was published in Health Affairs in 2013.^{vi}

- 2) The first analysis, focusing on 72-hour returns, was presented at ACEP 2015,^{vii} and at AMIA 2015,^{viii} and a final manuscript from this analysis was published in Academic Emergency Medicine in year 5.^{ix} For this study we collected de-identified patient data over a five-year study period from Healthix, an HIE in the New York metropolitan area. We measured site-specific 72-hour ED returns and compared these data to those obtained from a regional 31-site HIE (Healthix) and to those from a smaller, antecedent 11-site HIE. Though only ED visits were counted as index visits, either ED or inpatient revisits within 72-hours of the index visit were considered as early returns.
- 3) Additionally, we completed further bivariate analyses of factors associated with patients' decisions to return to a different hospital for an early (72-hour) ED return versus the same hospital, which were presented as abstracts at ACEP 2016^x and AMIA 2016.^{xi}
- 4) In an additional analysis we employed multilevel analysis over a five year study period of visit-level, patient-level, and hospital-level data to describe differences between initial ED visits resulting in *different-site* and *same-site* return visits.^{xx} Results from this analysis showed that expanding from site-specific data to an 11-site HIE (NYCLIX) allowed for a 6.4% increase in our ability to identify early (72-hour) ED returns, and expanding from site-specific data to a 31-site HIE (Healthix) allowed for a 11.2% increase in our ability to identify early (72-hour) ED returns, for a relative increase in our ability to identify early (72-hour) ED returns of 75% when expanding from the smaller HIE to the larger HIE.

Aim 3: Implement the new inter-institutional e-Quality measures in existing quality assurance (QA) and case management programs and evaluate their impact.

- 1) For early (72-hour) ED returns we prospectively tested the ability of a 31-hospital New York-based HIE to improve an existing single-center 72-hour return QA process between July 2016 and October 2016. For descriptive purposes, we counted the number of *same-site* 72-hour returns under the prior single-hospital QA process and compared this with the number of *different-site* 72-hour returns under the augmented study QA process. Separately, a single ED faculty member (not blinded to the study hypothesis) read the medical records of these 72-hour returns and determined which cases signified a quality concern needing any further QA action. These *different-site* 72-hour return cases with quality concerns were compiled into a qualitative table and select cases were described. This work was published and presented as an abstract at SAEM 2017^{xix}.
- 2) For frequent ED users, once our automated, real-time notification for frequent ED users was successfully implemented at Mount Sinai, we compared the performance to the existing EHR-based frequent ED user. The HIE-based notifications and EHR-based report were sent via secure email to the case management program during a pilot (identification-only) period, 7/14/16-10/22/16 and an enrollment period 10/23/16-11/20/16. The number of patients identified and enrolled in the case management program through the HIE were compared to the EHR-based notification^{xviii}.

Results (Principal Findings, Outcomes, Discussion, Conclusions, Significance, Implications).

Results

Aim 1. As mentioned above, preliminary results from these analyses from the first site were presented at both the American College of Emergency Physicians in October 2013ⁱ and at the American Medical Informatics Association in November 2013ⁱⁱ, and preliminary results of our analysis for all four sites was presented at SAEM in May of 2014.ⁱⁱⁱ An additional poster showing the use of a Cohen's kappa metric to validate the HIE data was presented at ACEP 2014.^{iv} A complete manuscript of the final multi-site analysis was presented as a proceedings paper through a podium presentation at AMIA 2014.^v The major findings of this work were to validate the use of HIE data for frequent ED user and early ED return measurement across four hospitals by comparing site-specific data from the HIE to data provided from each site's EHR. The following table summarizes the key findings from this work:

Table 1	Site 1		Site 2		Site 3		Site 4	
	EHR Count	HIE Count	EHR Count	HIE Count	EHR Count	HIE Count	EHR Count	HIE Count
Frequent Users	1,204	1,221	1,060	1,035	1,746	1,708	936	924
72 Hour Returns	8,299	8,456	7,237	7,093	12,243	12,045	5,476	5,431
Table 1, from the manuscript, shows the agreement between the EHR and HIE when the quality measures of the frequent ED users and the 72 hour returns were applied. Site-specific EHR and HIE counts are not significantly different with a p-value < 0.001.								

Aim 2. The following numbered items correspond with the enumerated published studies listed above for Aim 2 under Methods.

- 1) For number 1 above, published in Health Affairs, we found a 20% increase in our ability to identify frequent ED users, and a 16% increase in our ability to identify their visits when using HIE-wide data compared with site-specific data. Additionally, 28.8 percent of frequent ED users visited multiple sites during the study period versus 3.0 percent of all ED users (p<.001).
- 2) For number 2 above, published in Academic Emergency Medicine, our bivariate early (72-hour) ED return analysis found a total of 12,669,657 patient encounters across the 31 HIE EDs, including 6,352,829 encounters from the smaller 11-site HIE. Site-specific 72-hour return visit rates ranged from 1.1% to 15.2% (median 5.8%) among the individual 31 sites. When using the larger 31-site HIE to identify return visits to any site, individual EDs had a 72-hour return frequency of 1.8% to 15.5% (median 6.8%). Use of HIE data increased the ability to identify 72-hour ED returns

by an average of 11.16% [95% confidence interval = 11.10 to 11.22] compared with site-specific data.

- 3) For number 3 above, the abstracts presented a bivariate analysis of factors that lead to patients returning to a hospital different than the index hospital for an early (72-hour) return, and were presented at AMIA 2016 and ACEP 2016, as shown in the following figures:

Characteristics of initial visit that influence 72-hour returns to a different hospital (larger odds ratios (ORs) indicate greater likelihood of return visits to a different hospital)

	Male	Female
Return to different site	58840 (6.2%)	48851 (5.15%)
Return to same site	400417 (42.21%)	440908 (46.44%)
Male patient: OR=1.32 (CI=1.31-1.34)		
	Day visit (7AM-7PM)	Night visit (7PM-7AM)
Return to different site	53791 (5.67%)	53922 (5.68%)
Return to same site	375598 (39.58%)	465661 (49.07%)
Initial encounter is during the day (7AM-7PM): OR=1.24 (CI=1.22-1.25)		
	Initial hospital and patient in same county	Initial hospital and patient in different counties
Return to different site	76558 (8.07%)	31155 (3.28%)
Return to same site	613571 (64.66%)	227688 (23.99%)
Initial hospital and patient in same county: OR=0.91 (CI=0.90-0.92)		
	EM Residency present at initial hospital	No EM Residency at initial hospital
Return to different site	53085 (5.59%)	54628 (5.76%)
Return to same site	225406 (23.75%)	615853 (64.90%)
EM residency present at initial hospital: OR=2.66 (CI=2.62-2.69)		
	Initial hospital is an academic institution	Initial hospital is a community hospital
Return to different site	16679 (1.76%)	91034 (9.59%)
Return to same site	134388 (14.16%)	706871 (74.49%)
Initial encounter is at an academic institution: OR=0.96 (CI=0.94-0.98)		

Table 1. The odds ratios (p-value = 0.0001) reflect the likelihood of an initial encounter with the listed attribute to result in a return visit to a different hospital, when compared to initial encounters resulting in an early return to the same site (e.g. an initial visit to a hospital with an emergency medicine (EM) residency is 2.66 times more likely to have a return visit to a different hospital, when compared to early returns with the initial encounter at a site without an EM residency).

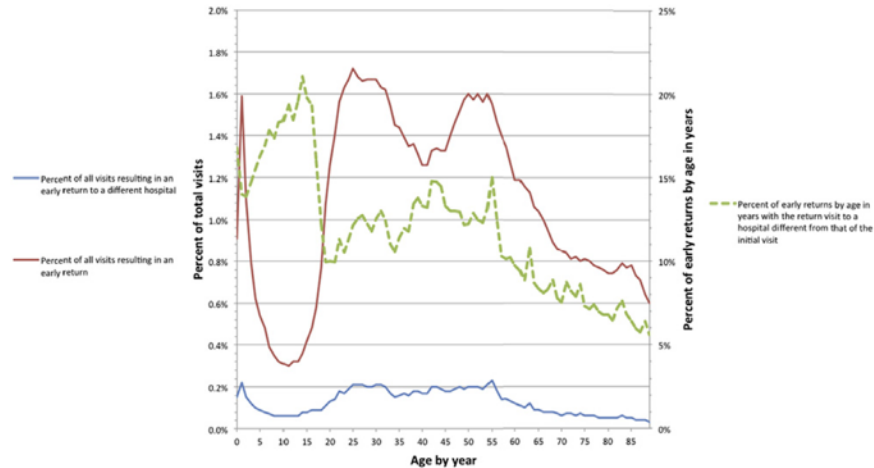


Figure 1. Percent of all total visits that result in early returns to a different site and percent of early return visits that are to a different site for each year of age.

- 4) For number 4 above, the multi-level analysis identified 12,621,159 patient visits to the 31 study EDs, including 841,259 *same-site* and 107,713 *different-site* return visits within 72 hours of initial ED presentation. We calculated odds ratios (OR) and 95% confidence intervals (CI) for the initial-visit characteristics' predictive relationship that any return visit would be at a *different* site: daytime visit (OR 1.10; CI 1.07-1.12), patient-hospital county concordance (OR 1.40; CI 1.36-1.44), male gender (OR 1.27; CI 1.24-1.30), age ≥ 65 (OR: 0.55; CI 0.53-0.57), sites with an ED residency (OR 0.41; CI 0.40-0.43), sites at an academic hospital (OR 1.12; CI 1.08-1.15), sites with high density of surrounding EDs (OR 1.73; CI 1.68-1.77), and sites with a high frequency of *same-site* return visits (OR: 0.10; CI 0.10 – 0.11).
- 5) Additionally, we published a concept paper peripherally related to this work on early (72-hour) returns, which reviewed the literature and described why the data do not support the use of 72-hour return frequency as an overall *performance measure*, described a conceptual framework for reviewing 72-hour return cases as a *screening tool* for quality assurance work.

- 6) Finally, we have another paper currently under review, which expands the analysis of frequent ED users described in number 1 above, to include data from across 31 hospitals, and describes the impact of expanding HIE size on the accuracy of frequent ED measurement.

Aim 3

- 1) For Early (72-hour) returns, 28,242 patients presented to the index ED over the four-month study period. Of these, 2,185 patients (7.7%) returned to one of 31 HIE-linked hospitals within 72 hours of their index ED visit, including 1,513 (5.4%) who re-presented to the index hospital and 672 (2.4%) who re-presented to a different hospital, representing a 44% increase in our identification of 72-hour returns over use of a single-site data source. Twenty *same-site* returns identified quality concerns from the index visit and 6 *different-site* returns identified quality concerns from the index visit, representing a 30% increase in our identification of quality concerns over a single-site data source. Examples of cases with a concerning *different-site* return included an elderly patient with urinary tract infection who was initially discharged without antibiotics and a patient with nonspecific neurologic complaints who on second visit was diagnosed with Zika-virus related Guillain-Barre syndrome
- 2) For frequent ED users, the following results were presented:

Table 1	HIE-Based Notifications		EHR-Based Report Only	
Period	Freq ED Users Identified	Enrolled in Case Mgmt	Freq ED Users Identified	Enrolled in Case Mgmt
Pilot	1020	–	786	–
Enrollment	343	16	89	3

Table 1: Pilot Period 7/14/17 to 10/22/16. Enrollment Period 10/23/16 to 11/20/16

Using the HIE notifications, we identified a substantially higher number of frequent ED users in the pilot and enrollment periods than using the EHR-based report (30% and 34% more respectively) and improved case management enrollment of frequent ED users during the enrollment period, with 16/343 (4.66%) enrolled through HIE-based notifications and 3/89 (3.37%) enrolled through the EHR-based report alone, a 38.4% relative increase in enrollment.

Discussion and Conclusions

Much was accomplished during this 5-year award. We validated the secondary use of community-wide, real-time clinical data from an HIE for our two electronic quality measures, namely frequent ED use and early (72-hour) ED returns, the results of which were presented at AMIA and published in their proceedings (Aim 1). We also performed numerous observation retrospective studies to show how HIE data can be leveraged to more accurately measure frequent ED use and early (72-hour) ED returns (Aim 2). Finally, we completed our implementation of both the frequent ED user notification service and the early (72-hour) ED

returns report, and presented abstracts showing the improved performance of these HIE-enabled electronic quality measures when compared to standard methods.

Work completed under this award demonstrates the improved ability to measure quality when HIE is used as a data source compared to commonly used, site-specific data. Because of the potential for additional secondary use cases of HIE data, this work likely only just scratches the surface. As a country, we took necessary first steps through the earlier phases of the Meaningful Use program to “electronify” much of the health data we generate through care delivery, and are only now beginning to prioritize interoperability. As we improve and employ data standards, and data become more fluid and transportable, following patients no matter where they travel across our fragmented healthcare system, new use cases for this new data layer that has been created through the implementation of query-based HIEs should become implemented. Timely and actionable information should be increasingly made available to clinicians at the point of clinical decision making through alerts, push notifications and other forms of clinical decision support. The lessons learned, and publically disseminated through this award, should help move the field forward.

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